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ABSTRACT

Skills tutorials for first year engineering students at the University of New South Wales, Australia, were introduced in order to develop an awareness of certain conceptual skills commonly exercised by practicing engineers. Particular skills include the manipulation of information in different forms, translation from one form to another, presentation of technical ideas, feasibility assessments, formulation of problems, and the use of models. The scheme also provides students opportunities to develop self-expression and to work cooperatively in a small group. The following program developments are described: formulation of aims of the exercises and the invention of problems, first trials and evaluation, and subsequent revision. A feature of the development strategy was the direct observation of the sessions and assessment of reactions and difficulties through interviews and administration of questionnaires. (SW)

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**Cultivation of Professional Engineering Skills
- Development of a tutorial method.**

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P R E F A C E

This occasional publication reports work carried out at the University of Strathclyde. Although the authors describe the introduction of a new tutorial component to a course in a Scottish university, their report was seen of especial relevance to engineering education in Australia. There is, in Australia, much concern about making tutorial provisions more effective, and, in engineering a number of teachers have expressed interest in exploring alternatives to traditional approaches in conducting problem-solving demonstrations and exercises. Within our own university it is likely that the purposes and organization of tutorial classes within engineering will again come under close scrutiny.

A second aspect which gives the report relevance is the similarity between the Scottish and Australian university systems - indeed the earlier founded universities in this country had as their model the Scottish system of university organization. Although our university system has had its own unique evolution since then, there still remain many characteristics in common. In both, engineering is a four year degree; and in both, the demographic characteristics of students are similar. When compared with English students our intakes for example are less specialised in their school preparation, are less highly 'selected' at intake and are more likely to be at risk of failure. We can expect therefore some of the problems to be similar.

We welcome this opportunity to publish the study by Dr. Boud and Dr. Gray.

Douglas Magin
Tertiary Education Research Centre
4.12.1978

SUMMARY

The main purpose of the scheme described in this paper is to cultivate an awareness of certain conceptual skills commonly exercised by practising engineers. The particular skills treated include the manipulation of information in different forms, and translation from one form to another; presentation of technical ideas; feasibility assessments; formulation of problems; and the use of models. The material has been designed for first year students as an introduction to the circumstances, considerations and open-ended strategies which are typical of professional engineering practice. The scheme also gives students opportunities to develop their powers of self-expression and to work cooperatively in a small group. A special small-group teaching procedure is used. This was adapted from the "skills session" method developed previously in the context of University Physics teaching. Various developmental aspects are described, including formulation of the aims of the exercises and the invention of problems; first trials and evaluation; and subsequent revision of the scheme which has now completed its third year of operation. A feature of the development strategy was the direct observation of the sessions by one of the authors who also assessed reactions and difficulties through interviews and questionnaires.

INTRODUCTION

It is our experience that most students coming to University at present have little knowledge of the art and practice of engineering. They are unfamiliar with the jargon, for example, what a "thrust-bearing" is or a "torque", or a "universal joint". They may have some impression of the *raison d'être* of an engineer but have not much understanding of the methods he uses. Their view of the subject matter is based on the picture of science which is commonly presented in school text books and examinations where the aim is to understand scientific principles rather than to learn how to make things work.

It is also common to find that first year students are reticent and do not appear to have much skill in self-expression. This may be partly due to strangeness in arriving at a new large institution, but it does seem to us that engineering students may have particular problems.

In addition to a lack of exposure to the practical aspects of engineering and to terminology, many students have academic weaknesses in particular areas of mathematics and science and this compounds the problem of unfamiliarity, causing difficulties for teachers of first year subjects in engineering.

Consideration of these typical problems and certain other local problems led to a reappraisal and reorganisation of the first year undergraduate engineering courses at the University of Strathclyde. In particular it was felt that the teaching of important topics in Engineering Science from the physicist's point of view in the first year and subsequently from the engineer's point of view in the second year, was an unnecessary

duplication which was also confusing to many students. Therefore in the case of the mechanical engineering course some of the material was transferred to a subject simply called "Engineering", this subject being added to the traditional list of first year subjects: Mathematics, Physics, Chemistry and Engineering Drawing. The change received considerable support from engineering staff and students alike as there was evidence that students who had no contact with the core of engineering in their first year were discouraged by being exposed only to "school subjects".

The introduction of the new course provided an opportunity to review the ways in which an introduction to engineering should be taught. It was agreed that the main aims should be:

- 1 to introduce and develop some basic Mechanical and Thermodynamic principles which form the core of mechanical engineering science, and
- 2 to convey some impression of engineering as a profession.

The methods which were to be used in pursuit of the second aim were not clearly worked out, but the main idea at that stage was that the course would be taught by engineering department staff who would talk like engineers and would use engineering illustrations in their lectures.

In the rest of the paper we wish to focus on one aspect of this course concerned with the second aim. Although it occupied only a small part of the total scheme it did represent a striking change in the teaching methods then in use in engineering at Strathclyde.

It was felt that the Engineering course should include a section which would approach some of the previously diagnosed problems in a new way. What was needed was some opportunities for students to

- (a) consider problems with an engineering rather than a pure science orientation
- (b) exercise and increase their skills of self-expression
- (c) work co-operatively in a small group situation.

It was also considered desirable that they should be able to do this using basic principles with which they were quite familiar. It was thought that if students were to develop "skills" then they should start to do so from a base of security through confidence in the subject matter. This meant that the scientific principles to be used were those familiar to them from high school.

Rather than starting from scratch in creating a new teaching method, it was decided to use the well tried engineering approach of adapting a design used elsewhere for a similar problem. One of us (DJB) had been involved in the Nuffield-funded Higher Education Learning Project in Physics HELP(P) and was conversant with the use of SKILLS SESSIONS, a teaching method originally developed in the Department of Physics at the University of Birmingham.¹

Although the HELP(P) skills sessions related to a different discipline and background, the aims were clearly similar, and it seemed possible that the experience available could be used to short-cut the development process at Strathclyde.

Format of Skills Sessions

The detailed format of the sessions depends on the tutor who is conducting the class, but the general form is as follows:

1. Introduction

The tutor presents a problem to a group of between twelve and sixteen students. He explains the relevance of the problem to engineering practice and how it fits in to some other ideas that the students will already have met. The problem is usually quite unlike the normal type of question that a student would see on a problems sheet or in an examination. It is frequently open-ended, it is based on very simple scientific principles, it can require judgement and estimation abilities on the part of the students, not all the necessary information is always given, the students have to decide how to present their answer, and the answer is not necessarily single-valued and clearly defined at the start. In short, the problems are much closer to real engineering problems.

No more than five minutes is normally spent on the introduction.

The students are divided into sub-groups of four or five arbitrarily, and each group is presented with either the same or similar problems.

2. The sub-groups

The three or four sub-groups of students work on their own without the tutor for about thirty minutes. Their instructions are to decide collectively how they will tackle the problem and be ready for any member of the group to present their solutions to the class at the end of their time. The tutor stands back from the discussions and does not interfere in the group activity. He may be consulted for information.

3. Presentation

The students gather in the total group and a spokesman from each sub-group is invited to describe his group's approach to the others. A blackboard or overhead projector is available to assist with this. Once the solutions are presented, students from other groups are encouraged

to ask questions and make comments about the solutions. Each group spokesman presents his group's findings in turn and discussion on the comparative merits of the (usually) different approaches ensues. The tutor mostly acts to draw out the students and takes care not to channel discussion along his preconceived lines.

4. Conclusions

On some occasions it is felt appropriate that the tutor makes some statement about how the students have tackled the problem, but not in the form of 'giving them the answer'. If the questions are carefully chosen and the discussion has been well conducted, then it should not be necessary or desirable for the tutor to state what he thinks they should have done. Invariably different groups take different paths to similar answers and it is often not possible even to judge what was the best approach.

The Exercise Material

The purpose of the exercise material as originally conceived was to develop certain kinds of conceptual skill which practising engineers use. Each skill session occupied one hour only and each student took part in four or sometimes five such sessions during their first year. It will be shown later that some modification of the aims became necessary.

The particular topics treated in the skill sessions as currently operated are:

1. Manipulation of information in alternative forms, i.e. graphical, algebraic, verbal description, etc., and 'translation' from one to another.
2. Presentation and explanation of technical ideas using sketches, diagrams and words.
3. Feasibility studies.

4. Use of non-mathematical alternatives in problem-solving.
5. Formulation of problems.

Examples of the exercises in their current form are given later.

IMPLEMENTATION OF SKILLS SESSIONS

Before describing our experience it is important to consider the context in which these developments took place. The introduction of new approaches to teaching is not a simple matter when 150 students are involved; it is necessary for a group of staff to be interested and committed to change and to be involved in making the decisions that they will have to implement.

For some years previously an informal group of mechanical engineering staff had met and considered how students could be educated in the art, practice or profession of engineering. Hence there was a climate of interest. The idea of skills sessions was discussed with members of this group and with other staff. Funds to aid their development in engineering were successfully sought from the Nuffield Foundation's Small Grants Scheme for teaching innovation. This support was used to provide short residential meetings away from the distracting day-to-day demands of the university where interested teachers were able to work out possible approaches.

The first meeting to develop the idea was addressed by Paul Black, the moving force of the skills session experiment in Birmingham. The remainder of the time was spent identifying topics which were thought to characterise conceptual skills in engineering. In addition to the five topics described earlier, other skills were identified. For example, professional engineers constantly make order-of-magnitude

estimates, particularly when checking the sense of calculated answers. They also have to learn to size up the possibility of errors and latitude in a result. Other differences between fully-trained engineers and novices were identified, for example the difficulties which students often find in accepting an arbitrary or non-theoretical basis for a design solution or as a way of making a start on a problem. It is often quite difficult for engineers who are familiar with the ways of thinking of engineering problems to devise problems which are simple enough for beginners to tackle.

At that stage a formal timetable allocation for skills sessions had not been agreed, and therefore in the first year they were fitted into a period officially allocated to laboratory work. This restricted the options somewhat with regard to group size, structure, availability of tutors and location, and therefore the early sessions were held rather unsuitably in the corner of a laboratory, with sometimes large groups of 16 - 20 students.

First Efforts 1975 - 76

It is probably true to say that students and staff alike found the early sessions more than a little sticky! Apart from the adverse environment previously mentioned, the staff had to become familiar with a new kind of exercise material and a new rôle. It was of some advantage that they had helped to invent the exercises as they then felt a greater obligation to make them work. Some of this uncertainty communicated itself to the students who were disturbed by the frequent changes of tutor rôle and other unusual features (to them) such as the fact that the exercises did not have definite answers. Where possible, tutors tried to spend one or more sessions looking on and learning before going into action themselves on the same exercise. This arrangement also benefited the 'performer', as he had someone to appeal to when in trouble, and had a source of more

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detached comment for 'post mortems'. In this way better strategies for presenting the exercises and facilitating useful discussion could be developed while the experience was fresh. In particular, the best strategy for dividing up and apportioning the parts of the exercise to the sub-groups to build in an element of competition, could be arrived at.

Gradually the skills of the tutors improved and as steps were also taken to improve the environment, the sessions became more relaxed and productive.

EVALUATION

Student responses

In addition to the sharing of experience gained through observation by tutors of each others teaching, a more formal evaluation exercise was mounted. One of us (DJB) observed most sessions and made notes. At the last session a questionnaire was distributed to all students. This contained 30 statements using students own language concerning various aspects of the sessions and their organisation, focussing on issues that had been raised in discussion with both staff and students. Fifty-three students (95% of those in attendance) all of whom had experienced three skills sessions, completed the questionnaire.

The following statements were very strongly supported (more than 60% agreed and less than 30% disagreed).

1. It is easier to have a discussion when the other students present their ideas clearly (48 agree, 3 not sure, 2 disagree).
2. It's good working in a small group (47, 2, 3).
3. The problems are more related to 'real' engineering than the class tutorial questions (40, 6, 9)

4. The problems discussed help me to learn how to think as an engineer (37, 7, 9).
5. I found the problems interesting (37, 5, 11).
6. I wish we could have been told the accepted answers (37, 3, 11).
7. We learn more about how to tackle problems because a group of students is left to work on their own for a while (35, 5, 13).
8. I didn't realise that there would be so many points of view on some of the questions (34, 7, 12).
9. The sessions help us communicate about the subject (33, 6, 12).
10. You don't get a chance to develop skills when the skills tutorials are so spread out during the year (32, 6, 14).
11. They are not going to help us with the exams. (31, 8, 12).

Strong disagreement was apparent for the following:

12. They were a complete waste of time (44, disagree, 1 not sure, 7 agree).
13. They have encouraged me to look something up in a book (43, 3, 8).
14. I can't see the point of the skills tutorials (39, 3, 11).
15. Skills tutorials ought to be abandoned (38, 5, 8).
16. They are boring (36, 3, 12).
17. The examples were unrealistic (34, 8, 10).
18. They were not relevant to the rest of the course (34, 5, 12).
19. The tutor doesn't give enough guidance during the skills tutorials (33, 4, 15).

Student opinion on the other statements was not so clear cut.

These results were very encouraging. The two areas of concern 'they are not going to help us with the exams' and 'they have not encouraged me to look up something in a book' are not surprising. The first echoes the response of Birmingham physics students - the present form of examination is not suited for testing the achievement of the skills which are pursued in

skills sessions. The second is consistent with student responses for other parts of the first year course - very little encourages them to use books of any kind.

An open ended part of the questionnaire gave an opportunity for students to give their views at greater length and several issues were raised that were not fully covered by the questions asked in the first part. 75% of the students made some response.

Students varied in the extent to which they appreciated the aims of the exercise. Some restated what they saw to be their purpose, for example, "I think 'skills tutorial' type work will be useful since engineers in industry will be asked to solve problems, and will not be allowed to do this in isolation, but in groups pooling their ideas at least some of the time. The practice in communication is therefore helpful". Some others found difficulty in knowing why they were doing it then and were confused by the use of the word 'skill' which they identified with some practical activity.

As can be seen from the ratings, many students were worried about not knowing what were the "correct" or "accepted" answers to the problems. They associated the skills session problems with the close-ended questions with which they were very familiar and found it frustrating that they did not get such straightforward answers or that such answers did not exist, "I think that the tutor should go through what is considered to be the correct procedure and conclusions so that we know whether or not we are adopting the correct approach". Many found difficulty in appreciating that there might not be a single correct approach to a problem. A minority of students seemed pleased that the problems were not so 'artificial' as those on the problem sheets and welcomed the greater sense

of relevance which they perceived.

Relevance was another factor over which students disagreed. Many remarks were made that the skills problems should be more realistic and related to the practice of engineering, "more often with actual examples of problems discussed by industrial engineers", "the examples are too basic and simplified", "maybe if they were related to actual problems that have occurred in the past, then we could compare our solutions with the original".

Students contrasted the skills tutorials with other parts of the course which they saw to be even less related to what they thought engineering would be.

In addition to this problem of intrinsic relevance, the frequent issue of extrinsic relevance appeared: "they are not going to help us with the exams". One student pointed out that he would disagree with this statement if he "knew that there was to be a discussion question in the exam". This was compounded by the anxiety of some students that the regular tutorials were not as much help as they would have wanted in preparation for the examinations. The statement, "we need more tutorials, but of a different type, for the Engineering lecture course" seemed to be supported for this reason, but a number of students wrote that they thought it difficult to judge the worth of the skills tutorials as they had had so few of them. Some were very enthusiastic and suggested that "we should have them every week". It was observed that almost all of the staff took their task very seriously and watched at least one of their colleagues conducting a tutorial before they tried themselves.

Staff Responses

Towards the end of the skills session trials, all staff who had taken part were circulated with a list of headings or issues concerning skills sessions and asked to comment under each heading. Six out of nine staff returned comments.

The three who did not return comments were members who had taken only one skills tutorial and it was understood that some staff found it difficult to judge with so little experience. The following discussion is based on the issues listed in the brief questionnaire and draws on both the responses of the staff who returned them and on the comments of others in informal discussions or interviews.

Aims

It became clear that some divergence had been perceived by staff between the aims originally proposed for the skills sessions and the aims realised in practice. The acquisition of conceptual skills gained less prominence as it was appreciated that little could be done in such a short period of time. Some of the altered aims cited by staff were:

"to get students to think about skills other than those which are involved in 'numerical' tutorials"

"to let them see that there may be more than one idea about the problem in hand"

"to give them the experience of working with others in a small group"

"to give them experience of communicating with others about engineering"

"to face some real engineering situations for the first time"

"to help students look more objectively at problems"

"to cultivate intensive thought by encouraging students to look at problems from a variety of points of views before plunging into detailed analysis"

Strengths

The staff saw the main strengths of the exercises in terms of getting the students to work with each other in group discussion; "the experience of discussing and putting forward views in public", "confidence in tackling problems" and getting to know each other and getting to know staff. They also thought it worthwhile that students had seen and had had experience of problems with many more factors, sometimes non-technical factors which they do not normally consider and had come to the "realisation that actual problems do not have an explicit answer".

Weaknesses

They were less successful as has been mentioned, in terms of one of the original aims - "they do little to develop the conceptual skills which are the excuse for the exercises" and in their ability to get all the students involved. Comments were made that "students need not participate if they do not feel inclined", "not everyone is drawn in", and "only the clever and attentive students benefited". (These comments should be considered within the skills sessions scheme only, and not in relation to the rest of the degree course. The participation of students was substantially higher than in the 'numerical' tutorials which one third of the students failed to attend).

A major weakness was seen to be the fact that there had been so few sessions that it would have been premature to judge that students would not get more involved if the sessions were held more regularly with greater continuity of staff and approach.

The formulation of some of the problems were identified as a weakness

by some, "the range of problems could be improved", "the standard of the skills tutorial problems could be improved." "I suggest more emphasis should be placed on problems where there are alternatives". One member of staff thought that there was a weakness in the preparation of students and he remarked on "surprising built-in preconceptions.....even at first year level. It was revealing that we don't do all the conditioning (of the students) as we are often told we do".

The following ideas for improvement were made by staff:

1. Increase the number of skills tutorials
2. Hold them at regular intervals
3. Ensure greater continuity
4. Reduce number of students to twelve (3 sub-groups of 4 or even less)
5. Find suitable rooms, not a lab or lecture theatre
6. De-bug the exercises in the light of experience, and build up a range of exercises
7. Use and develop the technique of using overhead projection
8. Forge better links with students' other work (standard tutorials)
9. Use elaborate problems towards the end

To this list, for the sake of completeness, the students' ideas can be added:

10. Develop exercises which have obvious relevance to real problems
11. The objectives of the skills tutorials should be reflected in the examinations, if they are really important.

Logistic Revisions

From the experience of the first trials it was possible to make a strong case for the continuation and expansion of skill sessions. However this would have been impossible but for the willingness of those responsible for the curriculum to allocate a second hour of time which had been originally dedicated to laboratory work. This made it possible to establish a complete schedule whereby each student progressed through five exercises in a logical sequence of topics. The resulting flexibility allowed the use of more suitable rooms and facilitated an arrangement whereby the membership of a given group could be stabilised over the first few exercises and the tutor stayed with a familiar group of students. As the sessions were thereby removed from the laboratory they ceased to be associated in the students' minds with laboratory activity and acquired an independent existence in which the separate purpose of skill sessions could be more clearly identified and accepted by students and tutors alike.

Revisions in content

During the first trials many ad hoc revisions had been made. However even after these were incorporated, the exercises still seemed to lack an "X factor" which was difficult to define. Careful reflection suggested that the deficient feature was engineering relevance. This was partly due to the lingering influence of the Birmingham examples which had after all been developed to suit the needs of physicists. However it is probably also true that the engineering staff who adapted these examples or invented new examples, found it as difficult as anyone else to shake off the tendency to think in terms of school-type science

exercises, this being a more pernicious influence than is perhaps recognised. Before the start of the second academic session of development therefore, a revision of all the exercises was made from the standpoint of hypothetical but nevertheless realistic engineering situations. That is, the question was asked "If this skill was being exercised in an industrial or professional context, what might be a typical set of surrounding circumstances?" Thus a rather dry exercise on the interpretation of graphs (see Fig 1a) acquired a new appearance (Fig 1b) through the addition of "more corroborative detail to lend artistic verisimilitude to an otherwise bald and unconvincing narrative"². It takes only a little imagination to describe a harassed Chief Engineer presented with a collection of apparently different graphs which he has to sort out. The process of exercise revision is probably not yet complete, but there is no doubt that it makes the exercises easier to present and catches the student's interest to a far greater extent.

Description of current exercises

It may be appreciated that more development effort has gone into these exercises than can be properly described here. However as it is proposed to publish "tutor kits" which may be of use to those who wish to run these exercises for themselves, the present comments will be confined to features of broader interest. The opening exercise on translation of information has been designed to break the students in gently, (Fig 1). The first question on the interpretation of graphs has a definite answer which gives them some confidence as they mostly recognise the correct interpretation. However the graphs include a number of blurring features such as false zeros, transposed axes and awkward scales, so that it is easy to develop a discussion about good graph presentation which is useful and in which everyone can participate. Questions 2 and 3 move into

areas of opinion which are much less cut-and-dried and we find that it is useful to have two sub-groups considering one question while the other two consider the other. As the groups tend to arrive at different conclusions this stimulates discussion. The students who have not considered a given question play just as useful a part as they can be appealed to along the lines "Did that point get across to you?"

The second exercise on explanation of technical ideas requires the use of an overhead projector (which is in any case invaluable for all the sessions). See Fig 2 (Appendix). Students do not have enough 'chalk skill' to make much of a blackboard drawing, but can produce reasonable sketches on acetate sheets which can be projected for all to see. More than one projector would be ideal, as the spokesmen often become more nervous during the walk from seat to projection point. Again each exercise must be given to more than one group or the vital competitive element is missed. A certain threshold level of presentation quality is essential as, if the explanation cannot be understood at all, the audience cannot begin to ask questions and lapses into bored indifference. However, normally this exercise promotes some hilarity and is a great "loosener-up". It is usual to include a sentence in the introduction along the lines - "You can be the most brilliant engineer ever, but if you can't explain your idea to someone else your chances of success will be slim". This point is usually taken.

The third exercise is presented as a feasibility study, see Fig 3 (Appendix). That is "work out whether this flow metering system is going to be satisfactory before the idea is converted into expensive and embarrassing hardware". We find it useful to divide up the task. One sub-group has to think about the flow controller/flow meter combination and give their best estimates of the maximum and minimum likely flows. Another sub-

group is set to think about the tolerance on tank volume and on clock accuracy. A third group has to figure out how to combine the conclusions of the others. They tend to consider only the given features and need to be encouraged to assess the non-specified aspects such as "how accurately can the clock be set?" or "how near to the desired indication can the operator judge the position of the rotameter." It helps to pass around a real flowmeter. Students are usually happier with this exercise as it involves a numerical answer, albeit one which depends heavily on the assumptions.

The fourth exercise was devised initially to relate to lecture course material on the stability of force equilibrium states, but quickly turned into an exercise which demonstrates the value of non-mathematical solution approaches. It may help to counter the constant conditioning which leads students to believe that the only respectable and valid solutions to a problem are produced by pencil, paper and mathematics. The illustration was based on the experience of a lecturer who witnessed an unfortunate accident to a motor patrol boat as it was being lifted on a crane sling. The task is to establish (a) a credible explanation of why the accident happened, and (b) a foolproof recommendation which will prevent a recurrence of the accident on the next attempt. In this case one sub-group is asked to provide a mathematical solution, a second examines the behaviour of a two-dimensional plywood and wire model, and a third uses a cardboard and drawing pin model to trace the locus of the load centre of gravity movement. (One has usually to take pity on the mathematical group at an early stage). The most convincing arguments usually emerge from the cardboard model. However the exercise tends to be too difficult for less able groups.

The last exercise attempts to combine some of the earlier skill concepts

and again arose from the industrial experience of a lecturer, see Fig 4 (Appendix). The tutor usually explains the meaning of "formulating the problem" as "finding out and stating what the problem is in specific terms", this being a key skill for engineers. Students are encouraged to think about quantities such as salinity, flow, cost, etc. in graphical terms and with some prodding, they usually get fairly close to an understanding of the problem.

COMPARISONS BETWEEN THE EXPERIENCES OF SKILLS TUTORIALS/SESSIONS IN PHYSICS, CHEMISTRY AND MECHANICAL ENGINEERING

The use of skills tutorials has now been monitored by the staff involved in physics at Birmingham and in chemistry and engineering at Strathclyde and certain common features emerge in the reactions of students.

Students are very critical of problems that they see to be 'unreal' or 'irrelevant'. This applies both to the extent to which the problems mirror problems in the 'real world' and in their relevance to the rest of their course. Unless they can see some application of the problems they are given, to the practice of their subject, they will be dissatisfied and not enter into the situation wholeheartedly. Also, if they see that the skills tutorial component of the course is not recognised by staff as important, especially if it is not reflected in examination questions, then the students see little reason to think it important and invest their energy in it. If anything, Strathclyde students in both subjects were less tolerant of 'artificial' problems than Birmingham physicists, but all groups wanted the skills tutorial component to fit in and relate closely to the rest of their course.

The other comparative observations that might be made about students' reactions is that students seem to become more favourable as they gain

experience of the method; this was very clear amongst the Strathclyde engineers. The chemists only had two sessions and their reactions were comparable to the engineers when they had only experienced two and both these groups were more critical of the ways in which the sessions were conducted than the physicists who had had them regularly throughout the year and whose staff had more experience with the teaching method.

CONCLUSIONS

Considerable knowledge has been gained by various groups of university teachers on the use of skills tutorials. The experience of those involved in HELP(P) is contained in their book on Small Group Teaching in Undergraduate Science³, and our work supports this in the engineering context. The question might be posed: Why are skills sessions so popular, for they certainly do have wide acceptance amongst people who have tried them. The answer to this in our view is, firstly, the idea is very simple. It is easy to describe the format and to give examples of how it can be used: such an explanation is sufficient for university teachers to try the idea. Secondly, it is easily adapted to various personal styles. We have seen it work with staff who adopt both authoritative and democratic stances in the classroom. Thirdly, it does not require any sophisticated appreciation of small group teaching methods. Observation of colleagues and practice were sufficient for engineering teachers to use the approach with their own groups to their own satisfaction.

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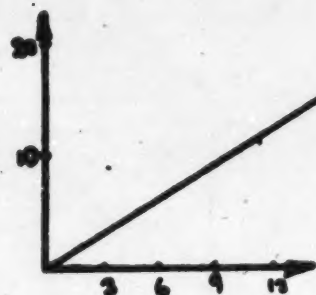
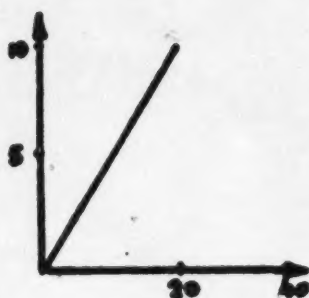
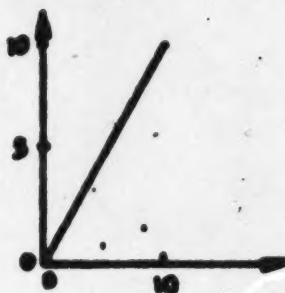
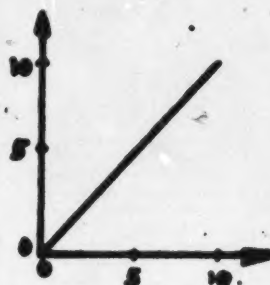
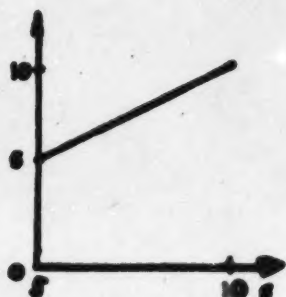
the exercise problems were also contributed by colleagues, in one form or another. The exercise sheets were prepared by Gordon Pert of the Centre for Educational Practice at the University of Strathclyde.

REFERENCES

1. Black P J, Griffith J A R and Powell W B "Skill Sessions"
Physics Education 9(1), January 1974, pp 18 - 23
2. Gilbert W S "The Mikado" - 1855
3. Ogborn, J (ed) "Small Group Teaching in Undergraduate
Science" London Heinemann Educational 1977, pp 136 - 158

Exercise on Verbal, Graphical and Algebraic Expression

1. The figures below show distance-time relationships. Do these graphs represent different or identical velocities?

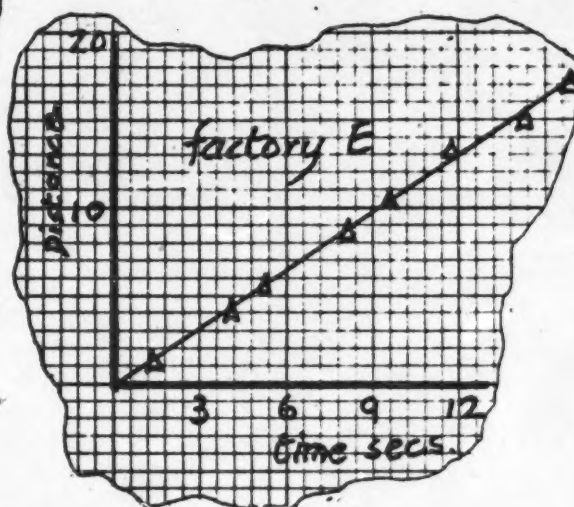
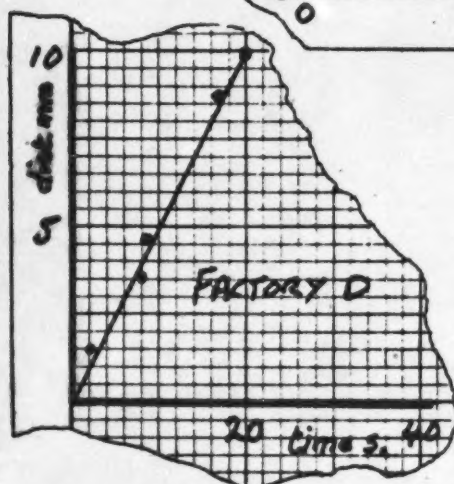
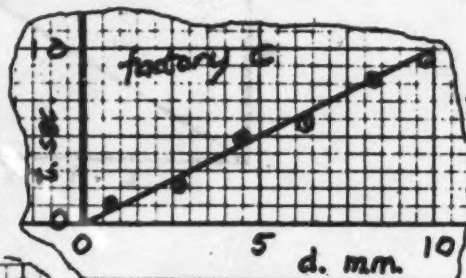
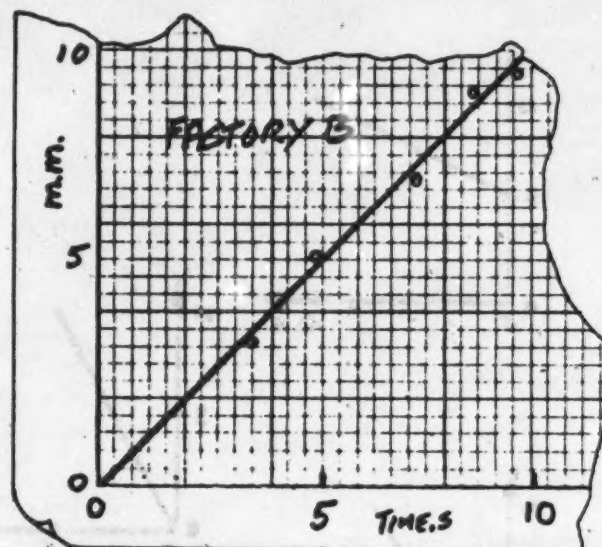
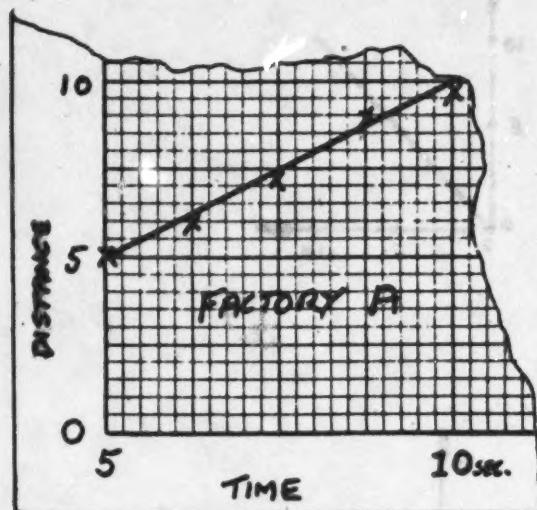


Original 'scientific' exercise sheet

FIGURE 1(a)

EXERCISE ON VERBAL, GRAPHICAL & ALGEBRAIC EXPRESSION

- The figures below show the results of tests carried out on supposedly identical plastics extrusion machines in different factories. Do they represent identical velocities?



Improved exercise sheet

FIGURE 1(b)



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2. The graph shown below was recorded near the base of a steam hammer during a single operation. What are the implications of this graph for people and property in the vicinity?

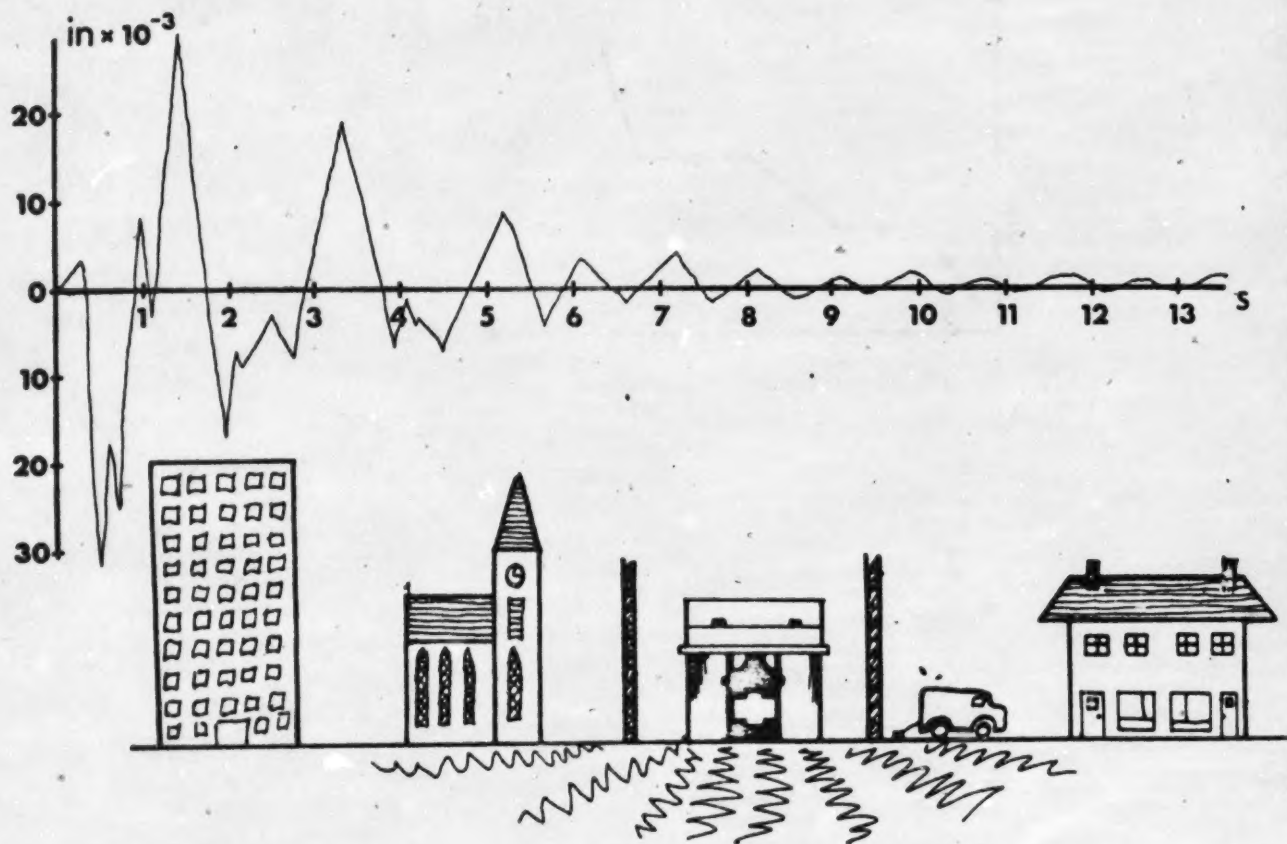


FIGURE 1 (c)



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3. The temperature/time relationship during heating of a substance used in fire warning devices is shown schematically below. What does the graph tell you?

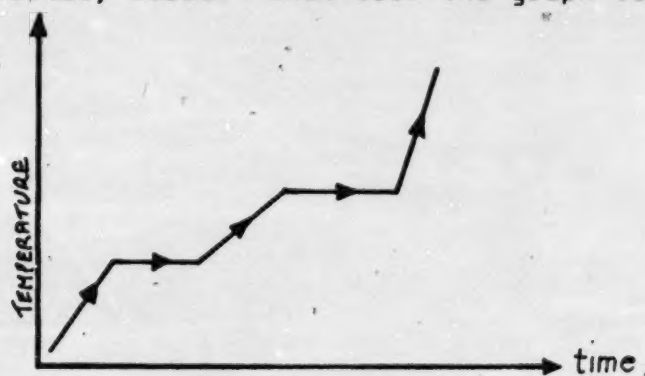


FIGURE 1 (d)



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4. Here are four equations:-

$$y = mx + c$$

$$y = Ax^2 + Bx$$

$$y = A \sin nt$$

$$h = \frac{P}{A} + \frac{Mx}{I}$$

Can these equations be related to the graphs in questions 1, 2 and 3?

FIGURE 1 (e)



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EXERCISE ON USE OF DIAGRAMS AND WORDS

Practising engineers spend much of their time explaining things to other people (who may not themselves be engineers).

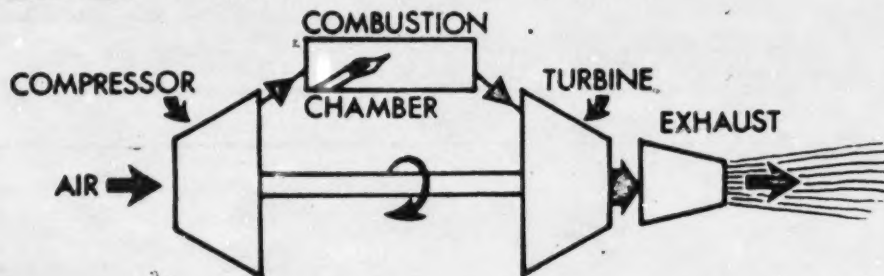
For this, an ability to draw and make use of simple clear diagrams is essential.

Take Sir Frank Whittle's verbal description of the jet engine:

"The maor organs of a turbo-jet engine are: a compressor, a combustion chamber assembly, a turbino, and an exhaust pipe ending in a jet nozzle. Large quantities of air drawn in at a front intake pass through these organs in that order."

Sir Frank Whittle.

The same points can be made diagrammatically:-



Prepare diagram(s) and a clear verbal or written explanation for the following examples.

1. What is the function of an outrigger on a canoe, and what mechanical principles are involved?
2. Why is the symbolic kind of ship's anchor shown on coats-of-arms, etc., an impractical piece of engineering?
3. A ship propulsion system consists of a diesel engine, a clutch, reduction gearbox, propeller shaft mounted in bearings and a propeller. It is important that the propeller thrust is not transmitted to the gearbox, clutch and engine, and that the torques are properly reacted by the ship structure. Explain how this could be achieved.



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EXERCISE ON CUMULATIVE INACCURACIES

The diagram shows an arrangement for filling a steel tank of nominal dimensions, 10m long x 4m wide x 3m high. The manufacturer of the flow controller guarantees that it will maintain the flow to $\pm 1\%$ of the initially set value and the flow meter indication will always be within $\pm 2\%$ of the true flow rate.

The operator sets the flow controller to give the desired flow rate reading (as nearly as he can) and then sets the time clock to switch off the flow when the tank ought to be full. What time should he set to avoid spillage, and what minimum level will then be in the tank?

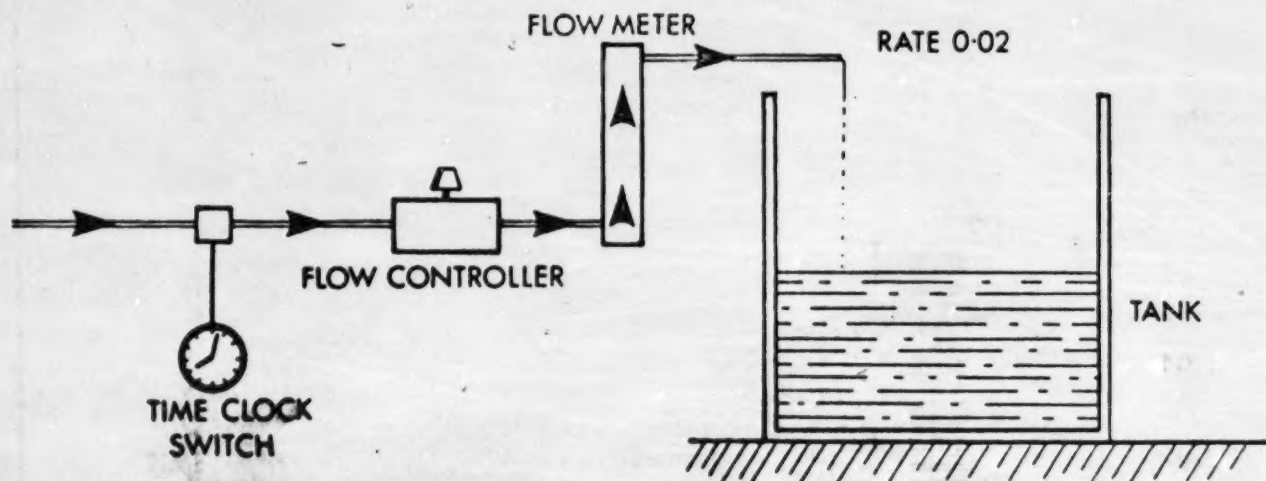


FIGURE 3



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FORMULATING THE PROBLEM

In a certain country where salt is precious, the accepted method of extracting salt from naturally-occurring salt and sand deposits is shown below in diagram form. The problem is to decide when to dump the exhausted bed and recharge with a fresh mixture, because water is also too expensive a commodity to continue washing beyond an economic stage.

A number of measurements could be made to determine how far the process has gone. Sand samples could be taken at intervals from the sand bed and sent to a local lab for salt determination, or a special instrument could be installed to permit continuous and accurate measurement of the salt concentration in the pipeline. Flow-meters could also be fitted in the water input line or the output salt line, or both.

Decide what needs to be measured and why? Show, in principle, how you would control the extraction process.

